SEE Measurement for the SDRAM and the Blackjack ASIC

By

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I. Introduction and Overview

This report describes the testing of various SDRAMs at the Brookhaven National Laboratory (BNL) and Texas A & M cyclotron. This section describes the basics of the test. The description of the BNL test area and facility are contained in section II. Section III contains the test setup and conditions of the test. Section IV contains the results and analyses and the conclusion is in section V.

The purpose of this test was to determine the SEE characteristics of an SDRAM and an ASIC under heavy ion radiation. The cross section of each device, for both Single Event Upsets (SEU) and Single Event Latch-up (SEL), as a function of ion Linear Energy Transfer (LET) was the primary goal. The SEU and SEL threshold of these devices was also determined. Another observation was any long term or total dose effects from the radiation.

A table of the devices is shown in Table 1. The devices specify similar reading and programming protocols.

Table 1. The devices tested in this study.

Device	Manufacturer	Memory	Code	Technology	SNs
SDRAM	Micron	64Mb		CMOS	
ASIC	LSI	Na			

Ancillary graphs and comments are in the appendix. Raw data is tabulated and annotated in this section also.

II. Facility Overview

Brookhaven

The SEU test facility at BNL is located in a dedicated target room in the Twin Tandem Van de Graff Accelerator (Room 4 – Building 901-A). The facility was built as a collaborative effort of several government agencies, including NASA, NSA, NRL, and USASDC, called the Single Event Facility Group. The facility was designed to provide a user friendly and efficient testing station for SEE studies.

The accelerator provides a wide range of ions and energies for SEE testing. Ion species can be changed in approximately 30 minutes while ion energies can be changes in approximately 10 minutes. The ions interact with the target in an approximately 10^{-4} torr chamber. The chamber can be repressurized and evacuated in approximately 10 minutes when a device change is desired. A list of ions used in this study is shown in Table 2.

Table 2.

Ion @ Energy	LET (MeV cm^2/mg)	Range in Si (microns)
Carbon @ 99MeV	1.4	106
Chlorine @ 210MeV	11.4	63.5
Iodine @ 329MeV	59.8	31.6
Nickel @ 265MeV	26.6	42.2

The interior of the chamber is electrically connected to the test area through an airtight bulkhead. The board on which the Devices Under Test (DUTs) reside is mounted on a moveable stage. The DUT maybe be moved in any of three directions. The DUT may also be rotated. An iris can change the diameter of the beam from 0.1 cm to 4 cm. The iris can rotate with the DUT to ensure beam profile. The beam can be completely positioned from the user console and all positioning information can be saved.

The calculation of the beam LET and range in a desired material is done automatically for each run and saved. Other saved information is the energy, fluence, and time of the run as well as the angle. The system recalculates the LET and adjusts for the fluence when the angle is changed. Hardcopies also are made for redundancy. SEU cross-section curves are generated as the experiment proceeds for easy double monitoring of the experiment.

TAMU

The SEU test facility at Texas A&M cyclotron is located on the campus of the university. The DOE and the State of Texas jointly support the facility. Institute staff constructed, and now operate, a K500 superconducting cyclotron and its advanced Electron-Cyclotron Resonance (ECR) ion sources. The facility was designed to provide a user friendly and efficient testing station for SEE studies. The ECR Ion Source is highly charged ions for injection into the cyclotron are produced by electron-ion collisions in magnetically confined plasma excited by microwave radiation. These ions are also used for atomic physics experiments on an adjacent high vacuum beamline.

The cyclotron has a dedicated SEE Testing Facility which is designed for advanced radiation testing of Very Large Scale Integrated (VLSI) circuits, this facility features a large-volume target chamber with a versatile target positioning assembly, and a variety of industry standard vacuum feed through connectors. The chambers upstream from the target chamber provide for the beam control, diagnostic and dosimetry measurements. A large variety of high-energy beams covering a broad range of LET has been developed specifically for this purpose. These beams have a high degree of uniformity over a large cross sectional area. More information can be found at http://cyclotron.tamu.edu/.

The accelerator provides a wide range of ions and energies for SEE testing. Ion species can be changed in approximately 180 minutes while ion energies cannot be changed mid-run. The ions interact with the target in an approximately 10^{-4} torr chamber. The chamber can be depressurized and evacuated in approximately 10 minutes when a device change is desired. The beam can also be run in open air if desired. A list of ions used in this study is shown in Table 2.

Table 3

Particle	Energy(MeV)	InitialLET(Si) (MeV cm2/mg)	Range µm	LETmax (MeV cm2/mg)	Range(LETmax) µm
Ne	546	1.74	799	9.65	790

Ar	1000	5.41	500	20.1	491
Kr	2100	19.2	336	41.4	315
Xe	3200	37.9	286	63.4	254

The interior of the chamber is electrically connected to the test area through an airtight bulkhead. The board on which the Devices Under Test (DUTs) reside is mounted on a moveable stage. The DUT maybe be moved in any of three directions. The DUT may also be rotated. A rectangular iris can changed the diameter of the beam from 0.1 cm to 4 cm in either direction. The beam can be completely positioned from the user console and all positioning information can be saved.

The calculation of the beam LET and range in a desired material is done automatically for each run and saved. Other saved information is the energy, fluence, and time of the run as well as the angle. The system recalculates the LET and adjusts for the fluence when the angle is changed. Hardcopies can be made for redundancy. SEU cross-section curves are generated as the experiment proceeds for easy double monitoring of the experiment.

III. Test Setup and Procedure

The test was comprised of two PCs, a power supply, and a specially designed test board. One PC controlled a HP6629A power supply. This allowed precision voltage control and latch-up detection and protection since the PC had millisecond control over the operation of the power supply. Latch-ups were recorded in a separate file.

A dedicated PC controls the test circuit board designed specifically for this SDRAM test to read and write to the DUTs. Specially made daughter boards allow each SDRAM type to be tested by the same test board. The address of each DUT can be accessed randomly and the address space can be accessed at a rate of 2185 addresses per second. This setup allows complete freedom to interact with the DUT. The address of a failure and the value at that address are recorded in a file for each run. This would allow for any structure in the SEEs or predilection for certain pattern failure or type of SEU to be seen. A depiction of the setup used is shown in Figure 1.

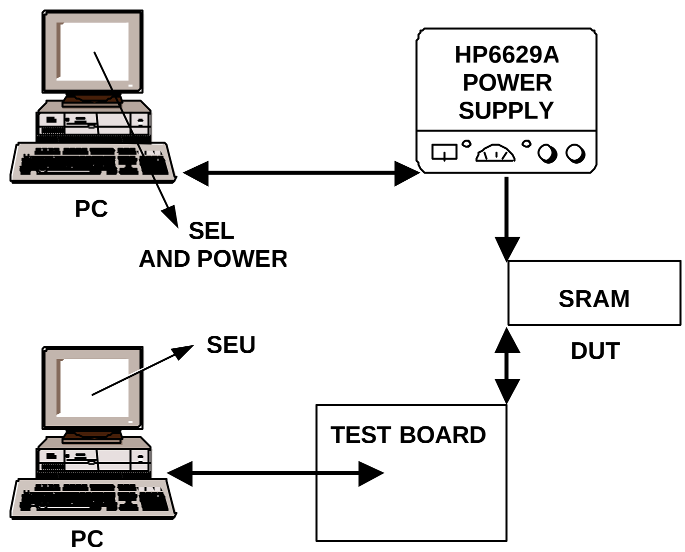

Figure 1. A schematic of the test system.

For this test, most of the radiation runs are done when the DUT is standing by with a known pattern written in the DUT. The PC cycles through the address space of the DUT, stores an address which has an error, along with the error value, and rewrites the correct pattern to the address. The most common pattern written to the device is checkerboard pattern, i.e. an 8-bit address would have 170 in address 0, 85 in address 1, 170 in address 2, and so on. Some tests were done while reading or writing data to test for susceptibility to SEE during such processes.

The Vdd voltage was always set to 5 volts and the operating temp was approximately 25 °C throughout the study.

IV. Results

SEU

All of the devices had similar results. All of the devices were programmed and read using the same handshaking protocol. To measure any catastrophic effects, one of each of the devices was exposed to more than 10^5 iodine ions (LET 60 MeV cm^2/mg) with no latch-up protection. All of these DUTs were seen to work after the exposure. No stuck bits or residual programming problems were seen in any of the devices.

Some exposures were done during programming or reading to determine any contribution these processes. No dependence was seen.

SDRAM

The devices upset readily under irradiation by heavy ions. The threshold is less than 1 MeV-cm^2/mg and saturation cross section averaged about for three devices to be 2.5 cm^2. Graphs are shown below.

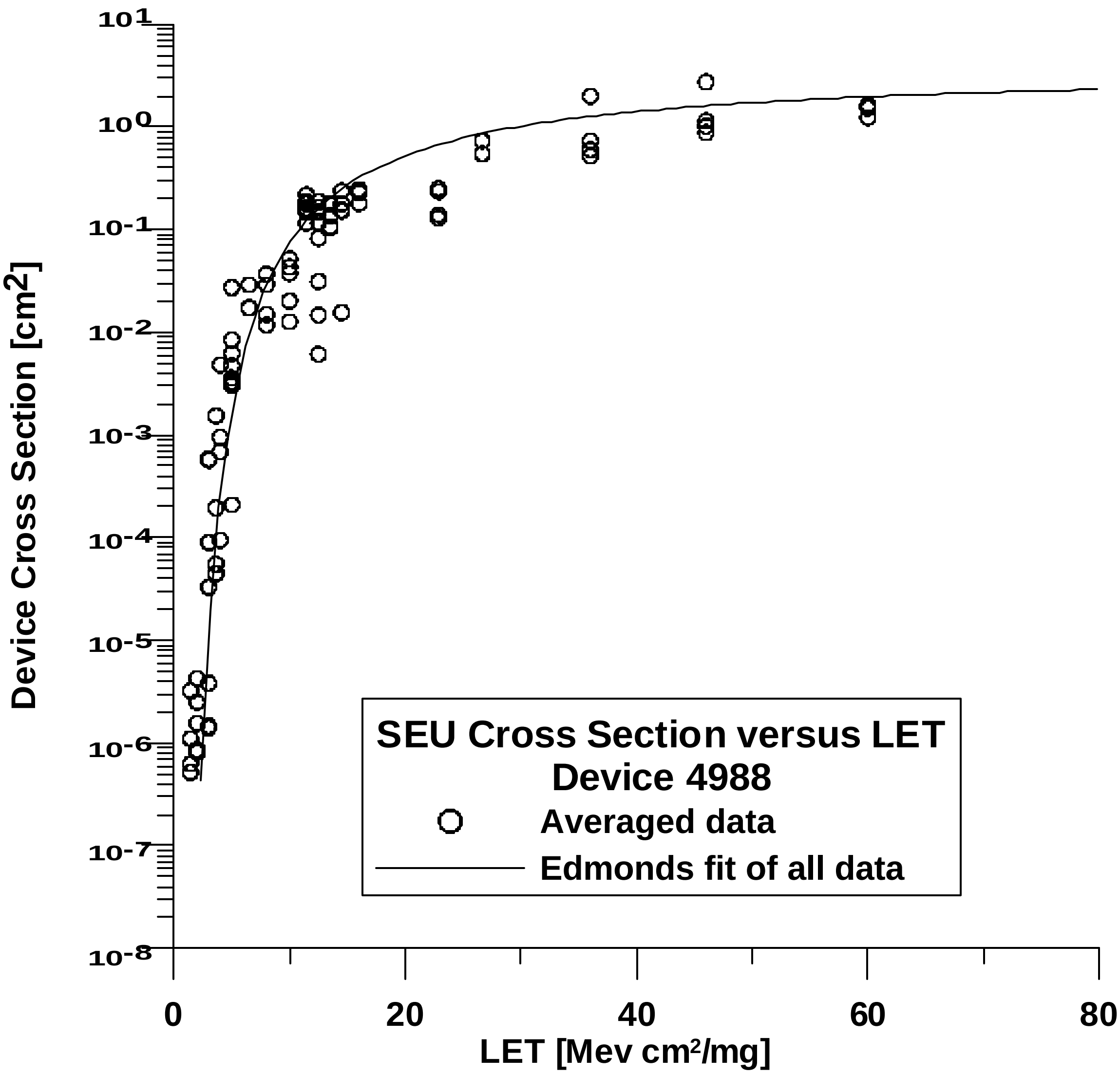

Figure 4. Fits were done to model this data. The solid curve is the Weibull fit to all data point. The dashed curve fits the lowest datum and ion types of 25 LET and above.

SEL

The devices proved relatively immune to SEL effects. Figure 5 shows the cross-section curve of the SELs. Latch-up levels were generally set at the maximum current limits in the specifications. Latch-ups increase with LET but the statistics were generally too low to generate meaningful fits. The MT5C2564 had a very high latch-up threshold; only one data point was attained, shown in Figure 5.

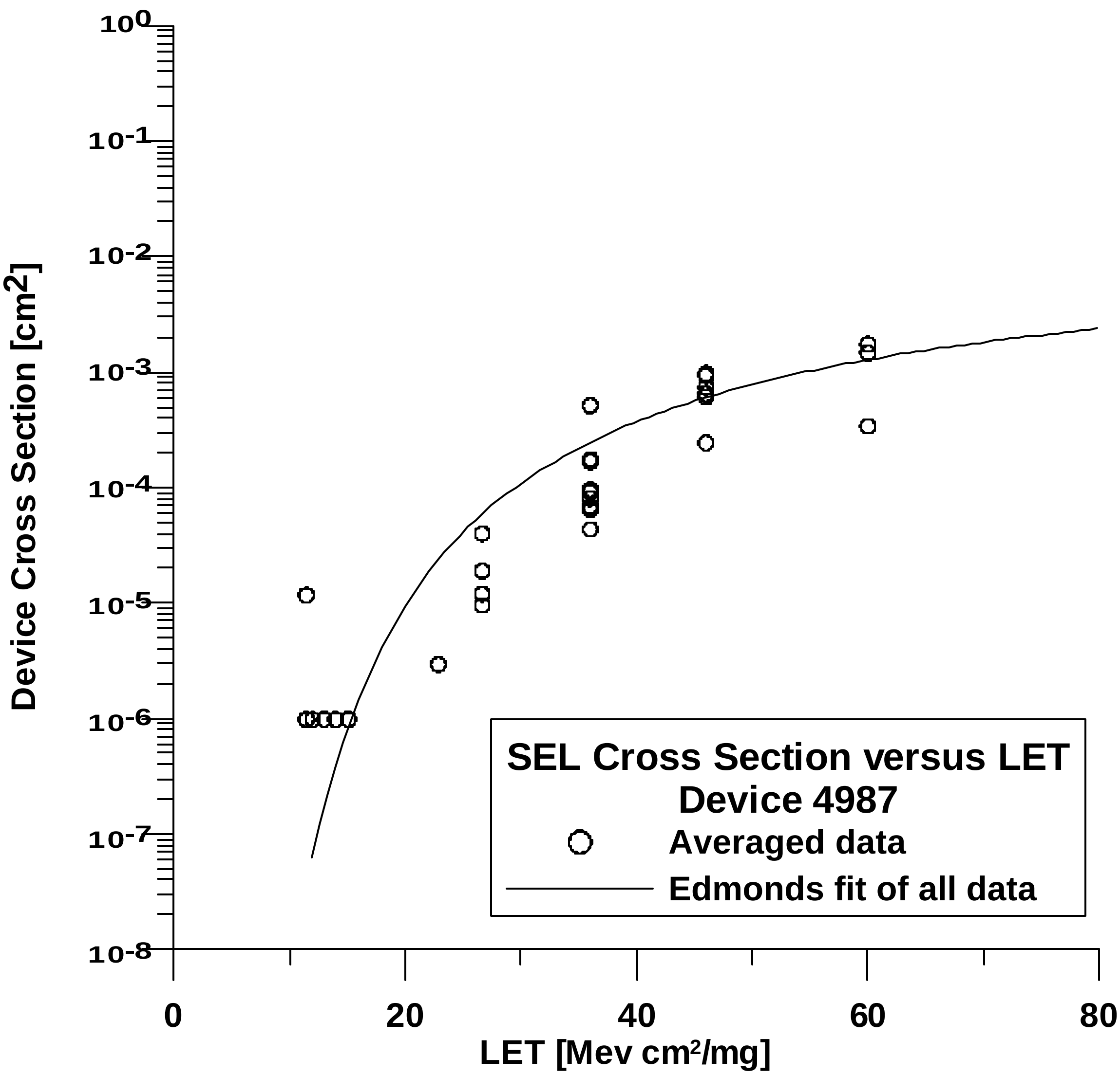

Figure 5. SDRAM SEL.

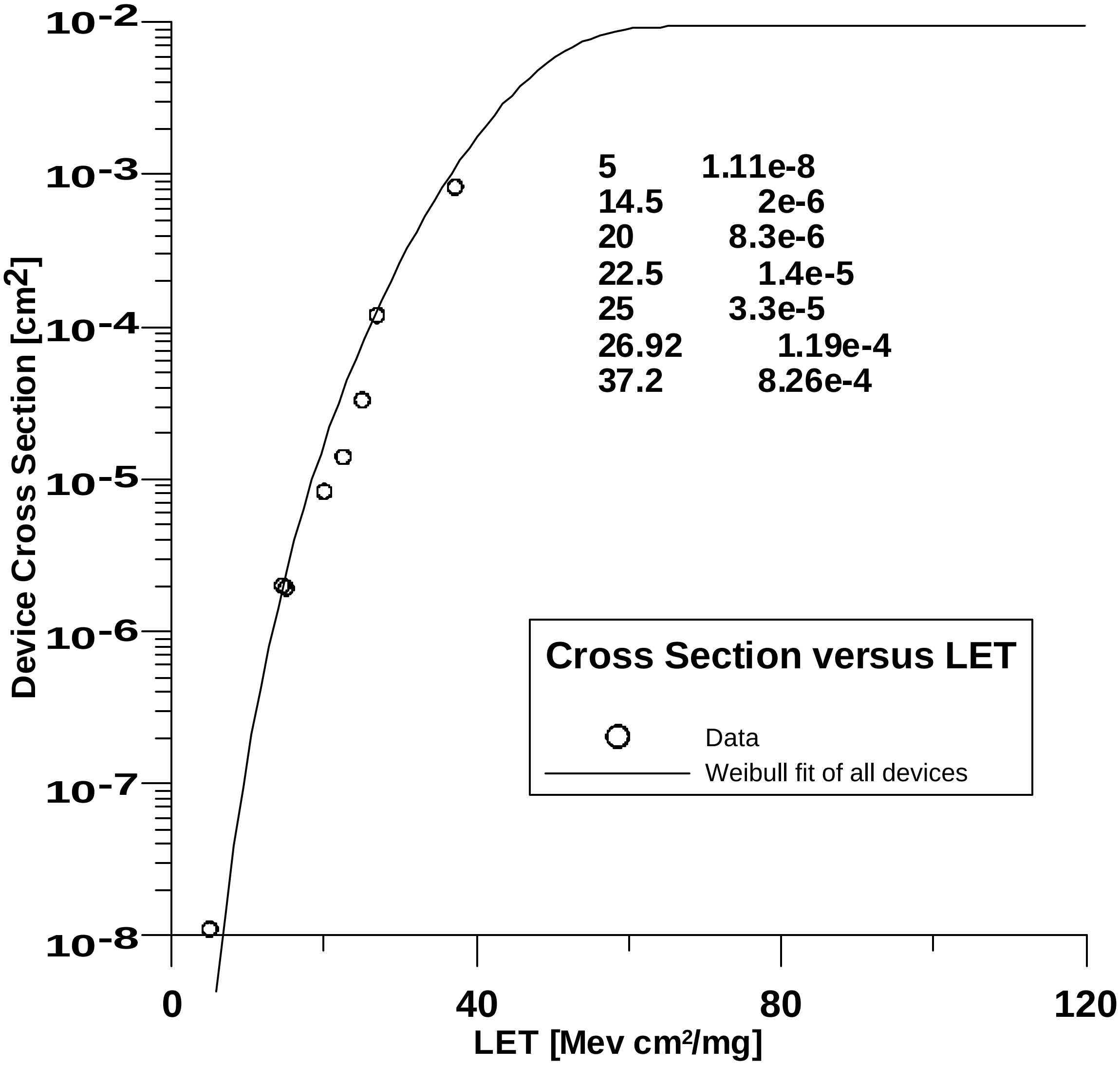

Figure 6. ASIC SEL.

V. Conclusion

Heavy ion data was obtained for each device. All devices were very soft in terms of SEU susceptibility. Thresholds for all three devices were all between 1 and 2 MeV cm^2/mg..

The devices were less prone to SELs than past devices have shown to be. No devices were seen to self-destruct or have stuck bits. A sample of each device was seen to survive under extreme irradiation with no latch-up protection. Table 3 shows the approximate thresholds for the devices as well as the saturation cross-sections.

Table 3.

Device	SEL Threshold (MeV cm^2/mg)	SEU Threshold (MeV cm^2/mg)	SEU Saturation Device Cross-section[cm2]
SDRAM	11	1	10e-3
ASIC	5	NA	NA